§8. Verification of the EC-wave Antenna Designing Scheme by Using a Set of Mirrors Identical with the U-port Antenna

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In LHD, eight transmission systems which connect the EC-wave power sources (gyrotrons) and the LHD vacuum vessel are used for power transmission to LHD plasmas. Each transmission system furnishes a beam injection antenna for EC-wave beam focusing and for controlling the beam direction. The antenna is composed of four (U-port antenna) or two (L- and O-port antennas) mirrors which are installed inside the LHD vacuum vessel. Two 82.7 GHz EC-wave beams, a 168 GHz beam and a 77 GHz beam are injected through four U-port antennas. Two 84 GHz beams are injected through two L-port antennas. A 168 GHz beam and an 84 GHz beam are injected through two O-port antennas.

To confirm the validity of the scheme for designing LHD antenna system, the performance of an antenna such as beam focusing and power transmission efficiency was investigated by making a set of mirrors identical with the LHD U-port antenna. A transmission component for 90 degrees bending (miterbend) at the halfway of the transmission line was removed and facing to the waveguide opening, the mirror set was installed at the correct position. By using real EC-wave power from 82.7 and 168 GHz gyrotrons, the beam profile was measured with IR-camera.

At the position corresponding to the LHD equatorial plane, apart 1.67 m from the final mirror, a Kapton-film target was set perpendicularly to the beam axis. Short pulse (4 ms) EC-wave power radiated from the waveguide opening is transmitted and focused by the 4 mirrors, and the temperature profile on the Kapton target was measured. Figure 1 shows the temperature profiles in two directions corresponding to toroidal and radial directions of LHD. The wave frequency is 82.7 GHz. According to the Gaussian fitting, the beam size (1/e radius of the electric field amplitude) is 58.1 mm in the toroidal direction and 20.2 mm in the radial direction.

Using 168 GHz power, the beam sizes at the equatorial plane were 58.9 mm in the toroidal direction and 12.3 mm in the radial direction. The designed waist sizes of the beam in the toroidal and radial directions are 50 mm and 15 mm, respectively for both the 82.7 and 168 GHz frequencies. It can be said that the measured temperature profiles are well fitted by the Gaussian fitting, and the beam sizes at the equatorial plane are nearly equal to the designed values.

By the same scheme, the evolutions of the beam sizes along the beam were measured at several positions between the final mirror and the equatorial plane. The beam sizes are plotted as functions of the distance from the final mirror in Fig. 2 with the analytic curves of the designed Gaussian beam. It also shows that the antenna designing scheme works well.

A compact dummy load to measure the power of the beam was inserted at several positions between the waveguide opening and the equatorial plane to evaluate the power transmission efficiency of the antenna. In Fig. 3, the result using 168 GHz power is plotted. The transmission efficiency is evaluated as 94 %. Using the 82.7 GHz power, it was 92 %. Both values are consistent with a theoretical evaluation of EC-wave power loss of 1~2 % per mirror.

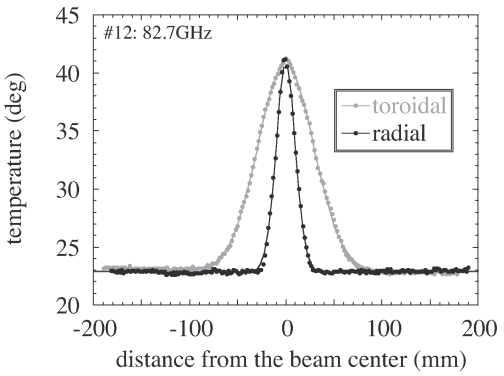

Fig. 1 Temperature profiles caused by the EC-wave power penetration on a Kapton target. Gaussian fitting curves are also plotted.

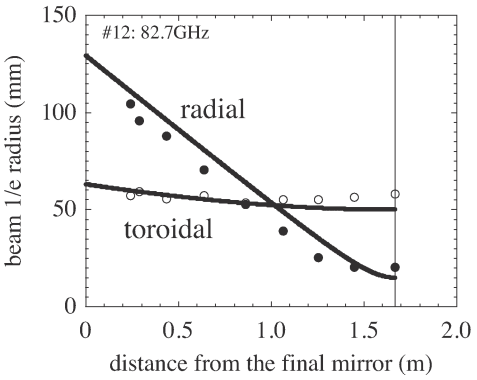

Fig. 2 Evolutions of the measured beam sizes in the toroidal and radial directions, plotted with the evolutions of the designed Gaussian beam sizes.

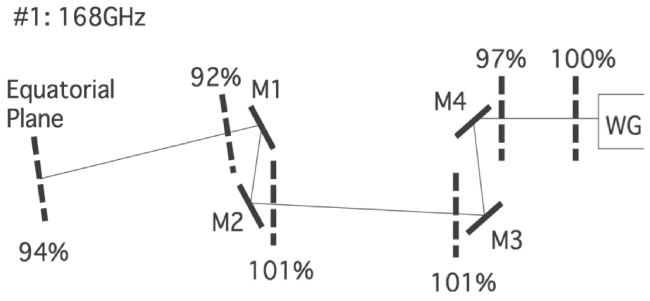

Fig. 3 Summary of the power transmission efficiency measurement. The positions where the dummy load was inserted are denoted by the dotted lines schematically.